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Life cycle assessment of nanoadsorbents at early stage technological development

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LCA of nano-adsorbents - Interpretation of laboratory results

Nano-adsorbents as an emerging product and a special application of nanomaterials can increasingly play an important role in the control and removal of environmental pollutants. An example of this is the use of nano-iron to remediate contaminated groundwater. However, even though particularly this example has been successfully applied in real scale, the application of nanomaterials as adsorbents is still an emerging technology at the early stages of development.

Hence, this study enables an environmental assessment of nano-adsorbents as an emerging product/technology based on the results from the laboratory. Two nano-adsorbents with graphene-based (MGO-NH-SH) and Fe_3O_4-based (Fe_3O_4@SiO-NH-SH) composites, which function with a similar thiol group for Hg(II) removal are compared at different stages of the production. Removal of mercury is important due to its historic cases of fatal contamination and its continued use. Although mercury must be removed from the contaminated sites it is still very relevant to make an LCA in order to ensure a balance between the impacts of producing the nanoadsorbent versus the avoided impact of the mercury that is being removed. The environmental impacts of synthesised adsorbents including energy use, climate change, water use, human toxicity, and ecotoxicity are investigated by a stepwise procedure during their synthesis processes, regarding their potential to remove mercury from polluted water (functional unit is removal of 1 kg of Hg(II)).

Accordingly, characterization results showed that although the process of the functionalization of nanoadsorbents leads to the increase of the adsorption capacity of nanoadsorbents, it is also paired with a significant enhancement of negative environmental impacts. A “what-if” perspective was applied to assess the uncertainties of using lab-scale data for parameters including amounts of acid (HCl + H_2SO_4), ammonia, ethanol, methanol, DCC (N,N'-dicyclohexylcarbodiimide), NHS (N-Hydroxysuccinimide), water recovery, and electricity.

The results of t-test comparing the impacts between MGO-NH-SH and Fe_3O_4@SiO-NH-SH estimated approximately 37, 34, 40, 31, and 26% more climate change, water use, energy use, human toxicity, and ecotoxicity, respectively for the latter. Sensitivity analysis were employed to determine the uncertainties for scale-up production and it is shown that especially potential reductions of electricity use, ethanol and DCC can reduce the impacts significantly.